

AN INSTRUMENT FOR MEASURING THE DECAY OF Mu-MESONS*

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ABSTRACT. An electronic instrument designed to study many problems connected with the decay of μ -mesons is discussed in detail. Special coincidence circuits, which differ from ordinary coincidence circuits in the fact that the output pulse from the special coincidence corresponds to the first input pulse, rather than to the last one, are used for recording the incoming mesons and the decay electrons. Many channels of delayed coincidences are used so that several points on the decay curve can be obtained simultaneously.

INTRODUCTION

An electronic instrument is described which can be used for measuring the life time of μ -mesons. The instrument was designed to study many problems connected with the decay of μ -mesons. The main features of the instrument are as follows :

1. Special coincidence circuits are used for recording the incoming mesons and the decay electrons.
2. Many channels of delayed coincidences are used so that several points on the decay curve can be obtained simultaneously.

Several circuits have been previously reported by Benade and Sard (1949), Rossi and Nereson (1943), Ticho and Schein (1947), and Hincks and Pontecorvo (1950). The present paper discusses in considerable details the new features introduced.

ARRANGEMENT OF G-M COUNTERS

The block diagram of the arrangement of G-M counter tubes, absorbers, and the circuit is given in figure 1. As is evident from the figure, the first three trays A_1 , A_2 , A_3 consisting of twelve G-M counters each, receive the incoming charged particles of the cosmic rays. The lead absorbers having a thickness of 8 cm or more filter out most of the soft component. Absorber I serves as a source of decay electrons. Those mesons which are of such energy that they can pass through first three

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trays, but cannot penetrate absorber I, will stop in it and give rise to decay electrons. The lower three trays B_1 , B_2 and B_3 consisting of 18 G-M

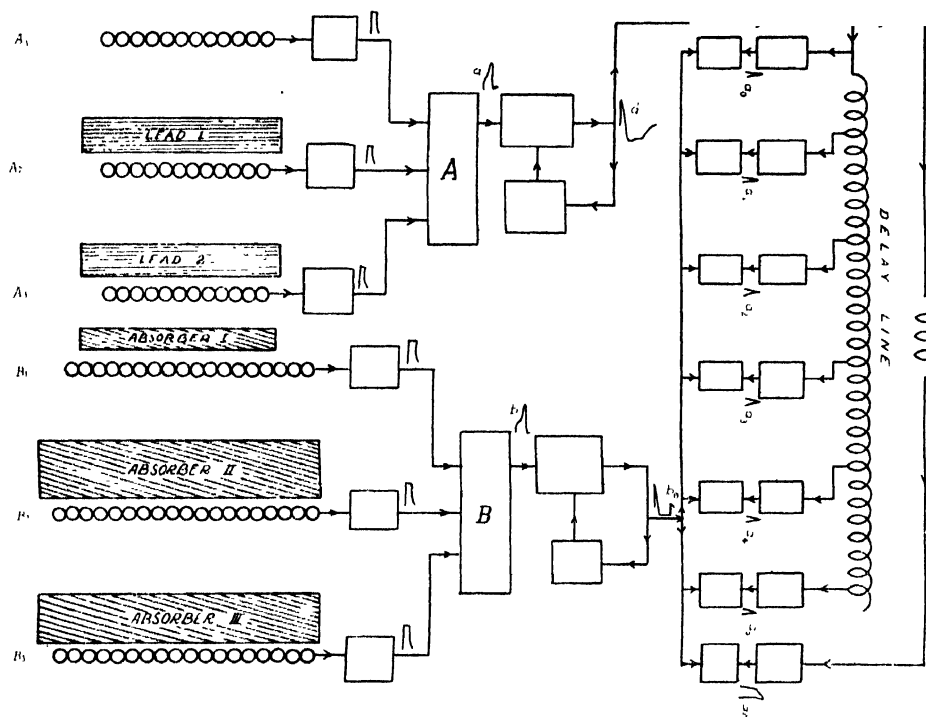


Fig. 1. Block diagram of counter arrangement, absorbers and the circuit.

counters each receive some of those decay electrons, which go through the solid angle defined by these three trays. Absorbers II and III may be used for determining the spectrum of decay electrons.

ELECTRONIC CIRCUITRY

General Description: The pulses from each of the six trays are fed to three staged amplifiers which give out positive pulses of about 20 volts, of nearly square shape, ten microseconds broad. A minimum negative input pulse of half a volt is required to saturate the amplifiers. The amplifiers, along with one cathode follower attached to each amplifier, are mounted just next to their respective trays on the frame itself.

The pulses from cathode followers of each amplifier are fed to the main electronic instrument by long leads from 1.5 metres to 2.5 metres in length. Due to the cathode followers, the pulses do not suffer any change in shape or size, in traversing these long leads. The pulses from the first three amplifiers are fed to a special coincidence circuit A ; and similarly, pulses from the other three amplifiers are fed to another exactly similar special coincidence circuit B . Pulse from circuit A , will be referred to as pulse a and that from circuit B will be referred to as pulse b .

These special coincidence circuits differ from ordinary coincidence circuits in the fact that the output pulse from the special coincidence corresponds to the first input pulse, rather than to the last one. In fact it comes t microseconds after the earliest pulse ($t=1.1$ microseconds in this case). Time t is kept nearly equal to the maximum time lag expected in the counter. This feature of the special coincidence technique is meant to reduce the fluctuation of time lags of the discharges in G-M counters as explained below.

There is a time lag between the time of the passing of an ionising particle through the G-M counter and the appearance of the pulse (Sands and Sard, 1947). This delay depends on the distance where ions are formed with respect to the central wire. If the ions are formed close to the wire, this delay will be less. But if they are formed farther off, it takes some time before the ions reach the wire and the charge spreads, thus causing delay in the appearance of the pulse with respect to the time of the passing of the particle. The time delay varies according to Gaussian distribution, (Sands and Sard, 1947; Corson and Wilson, 1948), and its value may, in certain cases, be as much as one microsecond which causes an uncertainty in the time measurements. The probability of the maximum time lag is about one in 10^4 in a single counter (Sands and Sard, 1947). But if a particle passes through three counters in succession, the probability of this delay in all the three counters at one time is reduced to one in 10^6 . It will mean that if the earliest of the pulses from the three counter trays initiates the coincidence pulse, the time lag will be reduced to a minimum value.

Pulses a and b are fed to two sharpener-cum-feed-back circuits, which serve to sharpen the pulses, and also paralyse the circuit for ten to fifteen microseconds after the passage of the pulse. While pulse a is changed to a positive pulse a' of width 1.5 microseconds followed by a negative gate of 10 microseconds, the pulse b is changed to a sharp positive pulse b_0 of an effective width ≤ 0.3 microseconds followed by a negative gate of 10 microseconds. The negative gate in both channels serves the same purpose as the anti-coincidence feature in the circuit of Ticho and Schein (Ticho, 1947). It can easily be seen that a particle passing through all the six trays will never be counted as a decay electron.

Pulse a' is fed to a delay line which consists of many sections, each section having a delay of about 0.3 microseconds. From six different points of this delay line pulses are taken and fed to equaliser circuits which give out positive pulses of nearly equal size and width, each being about one microsecond at the base. These will be referred to as a_0, a_1, a_2, a_3, a_4 and a_5 . Pulse a_0 has practically no delay with respect to b_0 , while pulses a_1, a_2, a_3, a_4 and a_5 are delayed by 1.1, 2.7, 4.2, 5.8 and 7.3 microseconds respectively with respect to pulse a_0 . The exact relative positions and shapes of the pulses are shown in figure 2(a).

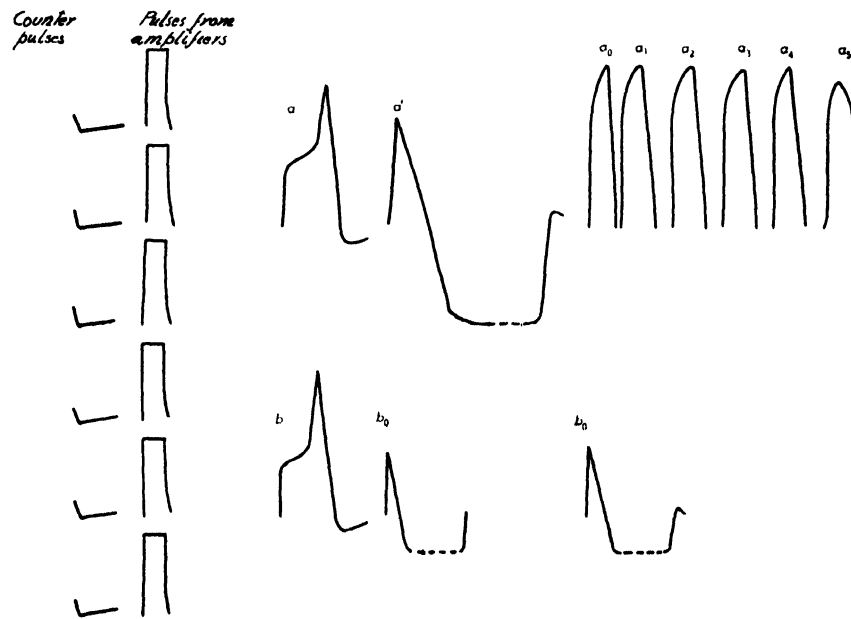


Fig. 2(a). Relative positions and shapes of the pulses in different parts of the circuit.

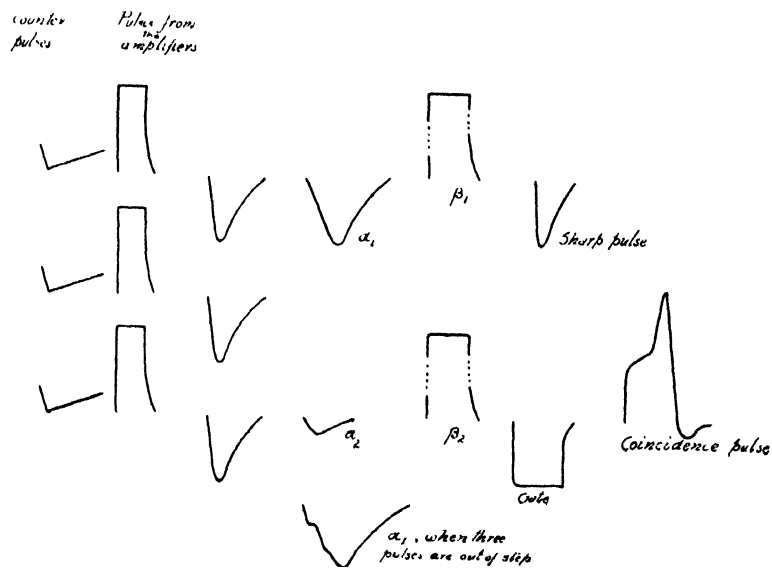


Fig. 2(b). Relative positions and shapes of pulses of different points of special coincidence circuit.

Each pulse a_0, a_1, a_2, a_3, a_4 and a_5 is fed to its corresponding input of the six double coincidence tubes, while pulse b_0 which is ≤ 0.3 microseconds in effective width is fed to the other input of the double coincidence tubes. The coincidence, between a_0 and b_0 is prompt coincidence, while others will be delayed coincidences. The relationship between different

pulses in the whole circuit shows that the prompt coincidence occurs when pulse b_0 appears 0.3 microseconds or less before and one microsecond or less after the a_0 pulse. Similarly for the other pulses, the effective interval in which coincidences can occur are:

- 1st channel (coincidence between a_1 and b_0)
when pulse b_0 appears within 0.8 and 1.8 microseconds after a_0 .
- 2nd channel (coincidence between a_2 and b_0)
when pulse b_0 appears within 2.4 and 3.4 microseconds after a_0 .
- 3rd channel (coincidence between a_3 and b_0)
when pulse b_0 appears within 3.9 and 4.8 microseconds after a_0 .
- 4th channel (coincidence between a_4 and b_0)
when pulse b_0 appears within 5.5 and 6.5 microseconds after a_0 .
- 5th channel (coincidence between a_5 and b_0)
when pulse b_0 appears within 7.0 and 8.0 microseconds after a_0 .

Another channel was added which recorded a delayed coincidence between pulse b_0 and a delayed gate of a variable width, which was opened by the pulse a' . This channel recorded delayed coincidences when b_0 came between one microsecond to six microseconds after a_0 .

Each of the delayed coincidence pulses was recorded by a univibrator of large time constant which made a neon bulb glow. The flashes of the neon bulbs connected to appropriate channels were recorded on a moving film.

DETAILED DESCRIPTION

Amplifiers: The circuit is shown in figure 3. The first tube 6AU6 is biased to near cut off point so that it is saturated with small pulses. Other

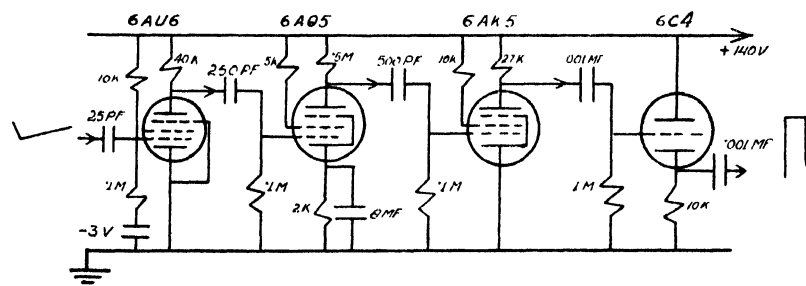


Fig. 3. Three staged amplifier for counter pulses

two tubes 6AQ5 and 6AK5 are sharp cut off pentodes giving out a positive pulse of a sharp first edge and a flat top. Tube 6C4 serves as a cathode follower.

Special Coincidence Circuit: Its detailed diagram is shown in figure 4. Each of the three positive pulses from the amplifiers is fed to a cathode coupled univibrator through a small capacity of 25 PF. The univibrator

gives out a sharp negative pulse, the size of which can be changed by adjusting the potentiometer R_1 . The three negative pulses are added

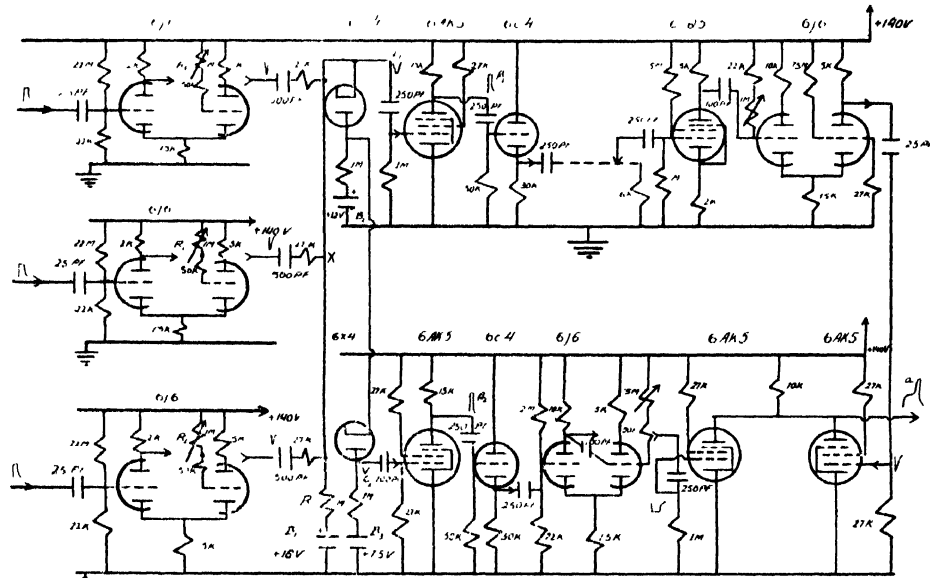


Fig. 4. Detailed diagram of special coincidence circuit

together over a resistance R_2 . If three pulses come at the same time the resultant pulse at point X will be a triangular pulse; but if in the extreme case the three come after one another, the pulse α_1 will have the shape shown in figure 2(b). Pulse α_1 is fed to a set of two diode discriminators in series. Due to the positive biases, the pulses can pass through the diodes only if their size is more than a given minimum, determined by the biases. The biases are adjusted such that the pulse passes the second diode only if the pulse α_1 is due to the sum of three pulses. Naturally the pulse α_2 at the plate of second diode will be a coincidence pulse, while the first edge of the pulse α_1 at the cathode of the first diode will correspond to the earliest input pulse. Both pulses α_1 and α_2 are fed to amplifier tubes 6AK5. The first edge of the pulse α_1 saturates its amplifying tube, while the pulse α_2 saturates the other tube. Pulse β_1 at the end of the first amplifier corresponds to the earliest of the pulses and pulse β_2 at the end of the second amplifier corresponds to the latest. Pulse β_1 after a cathode follower is fed to a delay line which delays it for 1.1 microsecond. After amplifying and sharpening this pulse with two tubes, it is fed to one input of a double coincidence. On the other hand, pulse β_2 is fed to a gating univibrator which gives out a negative gate of nearly two microseconds. The gate is fed to the other input of the double coincidence. The resultant coincidence pulse is shown in figure 2(b). The upper left edge of the coincidence pulse is due to the earliest pulse and as is clear from the previous description: this edge will always appear after a fixed time interval

Sharpeners-cum-Feed-Back :

Diagram of the circuit to which pulse a is fed is shown in figure 5. The first tube 6J6 acts as a *discriminator*. The potentiometer P_1 is set at such a value that the tube is triggered only by the upper left edge of the coincidence pulse. The negative output is applied to one of the grids of a 6J6 tube which works as an anti-coincidence tube. As the other grid of the tube is biased beyond cut-off, a positive pulse comes out which is applied to a cathode follower. This positive pulse, after being inverted is applied to a gating circuit which gives out a fifteen microseconds positive pulse. This gate is fed to the biased grid of the anti-coincidence tube. The result is a sharp positive pulse followed by a negative gate. The sharpness of the pulse can be increased by reducing the bias of the anti-coincidence tube.

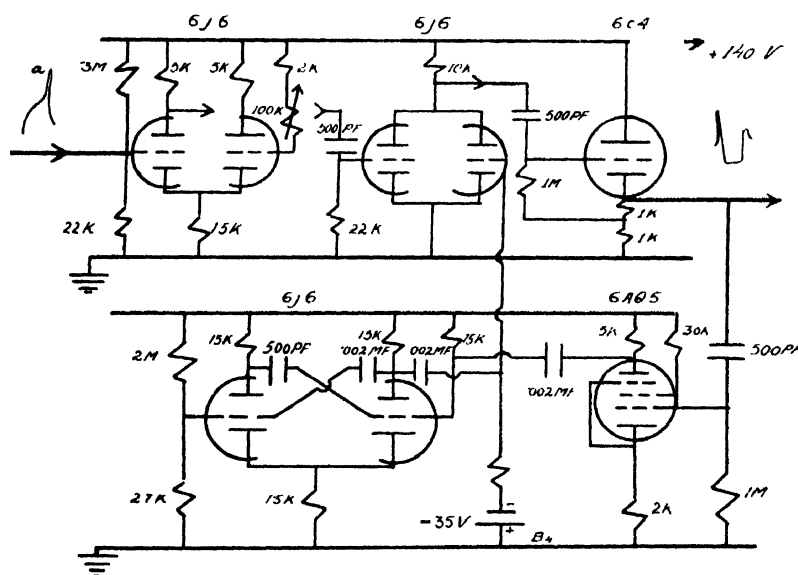


Fig. 5. Detailed diagram of sharpener-cum-feed-back.

The second coincidence pulse b is also applied to an exactly similar circuit described above, except that the constants of the first tube are changed to secure a sharp pulse of fast rise time. The bias voltage is also kept less than that in the above case for the same reason.

It was tested that the change of frequency of input pulses upto 20,000 per second did not in any way affect the output pulses a' and b_0 .

Delayed Coincidence:

The delay line to which pulse a' is fed was made in the laboratory, and consists of large number of ebonite cored inductances of nearly equal value, different points of which were grounded through condensers, making it a

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